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Permion - Specialty Membranes
Radiation Chemistry
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Water Resources Technology

DEVELOPMENT OF A PROTOTYPE PLASTIC SPACE ERECTABLE SATELLITE

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1.0 INTRODUCTION

During the current reporting period mechanical and electrical resistance tests have been performed on plated and plated-bonded Rexwell MX-44 polyethylene mesh. Additionally, samples of Sea Space thin polyethylene film (0.15 mil) were irradiated and subsequently heat treated in air and nitrogen. Tensile and shrinkage tests were then performed on the samples to determine the effects of irradiation, heat and oxidation on the film. A 1 mil high density polyethylene film has been selected for initial tests to determine the feasibility of irradiating, extracting, heat treating, perforating, and plating thin polyethylene film. The film selected is Marlex 6009 made by Phillips Chemical Co. This has been done so as to determine the processing problems on a less costly representative polyethylene film.

Finally, work has been started in finding companies for ultrasonic bonding, irradiating and perforating thin polyethylene film.

2.0 PLATED MESH TESTS

2.1 Mechanical Testing

Tensile and flexural rigidity tests have been performed on the Rexwell mesh through its various stages of processing. Table 1 is a summary of the testing results.

The tests indicate that there is a general increase in strength and rigidity (and stiffness) of the material with processing. This can be seen from the increasing values of yield force, F_y, and flexural rigidity, G, with processing.

The mechanical properties of the bonded mesh are also included in Table 1. It can be seen that there is a large decrease in strength at the bond. This loss in strength is the same for both bonds with coated copper and without. The loss in strength is caused by stress concentrations at the edge of the bond. In all tensile tests failure occurred at this location.

2.2 Electrical Continuity

Electrical resistance measurements were taken on 1 inch square samples of plated Rexwell MX-44 mesh during tensile tests. The actual data points are plotted vs. strain in Figure 1 and 2 for five samples. It can be seen from the graphs that the maximum specified resistance of 2 ohms/sq. occurs at approximately 20% strain; after which there is a very rapid loss in continuity (rapid increase in resistance).

Resistance measurements were also taken across the bonded mesh. Results indicate, see Figure 3 and 4, that the continuity across the bond is much less than in the plated mesh itself. Additionally, losses in continuity occur more rapidly with increasing strain for the bonded plated mesh.

In fact, after approximately 4% strain there is nearly no continuity. These results for the bonded mesh may be expected since there is not really a true bond between the plated pieces of mesh.

Table 1

Results of Mechanical Tests

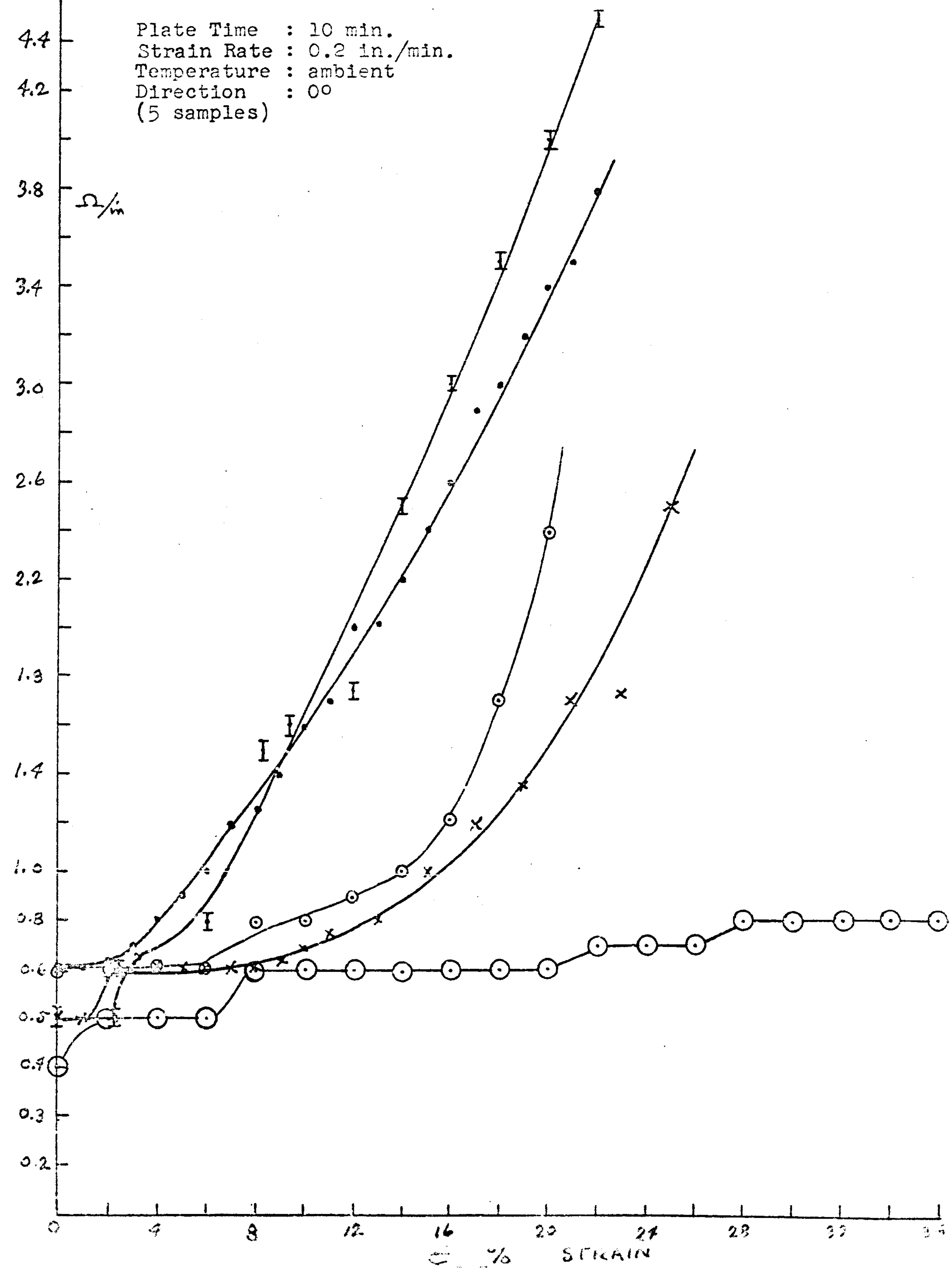
Direction Degrees	F_y (lbs./in.)	F_u (lbs./in.)	ϵ_y (%)	ϵ_u (%)	ϵ_m (%)	E (psi x 10^{-5})	G (lb.ft. x 10^{+5})
UNPROCESSED MESH							
0	10.9±0.5	18.3±1.3	7 ±0.8	807±67	827±63	0.72±.08	83.0±10.9
45	12.0±0.4	13.7±0.9	27.7±3.8	591±75	723±60	-	104.1±26.4
90	14.0±0.8	16.4±1.4	8.4±1.0	778±69	798±120	0.59±.07	193.0±55.5
IRRADIATED MESH							
0	11.7±0.6	13.7±0.9	7.2±1.2	353±15	411±23	0.66±0.9	122.1±16.6
45	11.9±0.3	13.8±0.8	25.0±1.5	306±36	469±53	-	129.0±17.0
90	15.6±1.4	15.6±1.4	7.2±1.8	7.2±1.8	253±71	0.70±1.4	221.7±67.3
IRRADIATED-HEAT TREATED MESH							
0	12.9±1.2	14.5±1.2	7.5±1.7	303±29	345±30	0.80±.20	134.0±11.1
45	13.1±2.0	14.8±4.0	42.0±2.0	228±28	385±20	-	144.0±10.5
90	18.8±1.7	21.5±2.7	9.2±3.0	167±66	263±30	0.69±.25	311.7±36.0
IRRADIATED-HEAT TREATED-PLATED MESH							
0	15.7±0.7	14.6±0.9	5.0±0.0	163±31	217±31	1.23±.06	157.6±32.9
45	13.0±0.3	13.6±0.3	40.0±0.0	75±19	108±38	-	201.6±27.4
90	19.4±0.9	17.1±0.4	7.5±1.7	20±3	85±7	0.81±.18	414.4±72.5
IRRADIATED-HEAT TREATED-PLATED-BONDED* MESH							
0	8.6±1.0	-	4.6±0.5	-	31±30	0.75±0.17	-
90	15.9±0.6	-	7.0±2.0	-	35±12	0.77±0.22	-
IRRADIATED-HEAT TREATED-PLATED BONDED** MESH							
0	8.8±2.9	-	4.0±0.3	-	33±25	0.95±0.19	-
90	15.3±2.3	-	5.0±1.0	-	27±3	0.86±0.13	-

* Copper removed from bonded area with nitric acid

**Copper not removed from bonded area.

Instron tensile test; strain rate 2 in./min., ambient temperature

Figure 1 RESISTANCE VS. STRAIN CURVE PLATED REXWELL MX-44 MESH



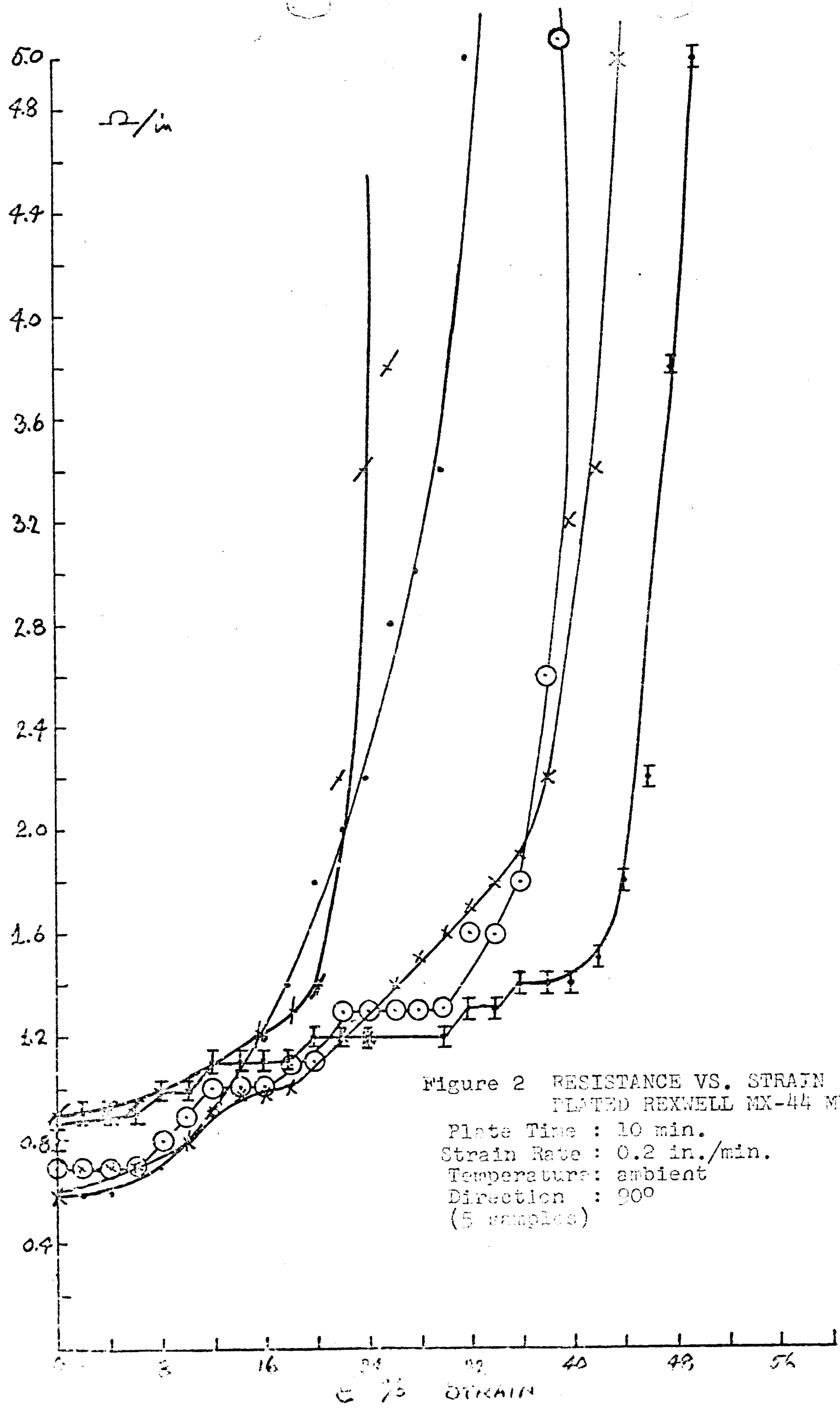


Figure 2 RESISTANCE VS. STRAIN CURVE
PLATED REXWELL MX-44 MESH

Plate Time : 10 min.
Strain Rate : 0.2 in./min.
Temperature: ambient
Direction : 90°
(5 samples)

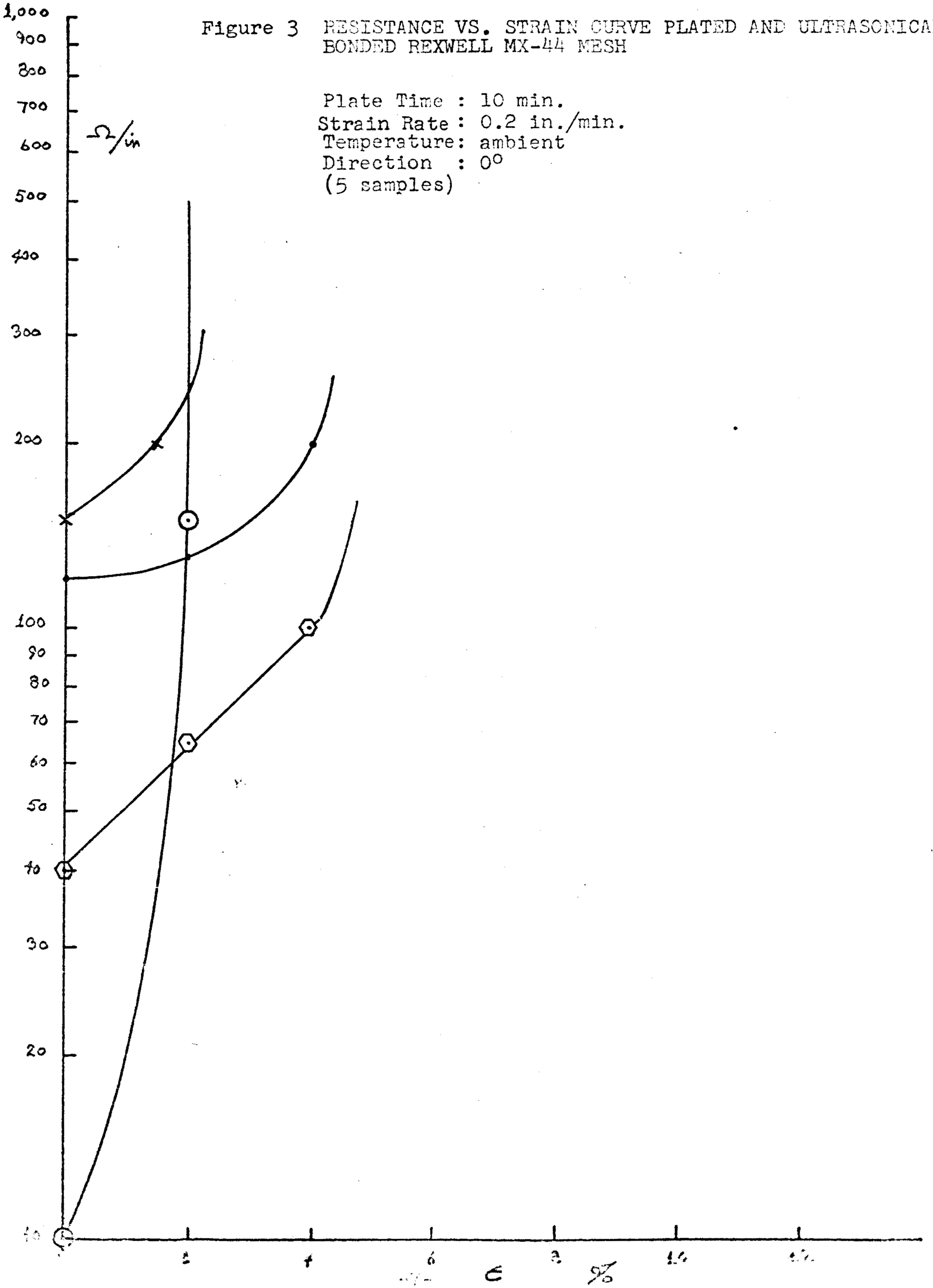
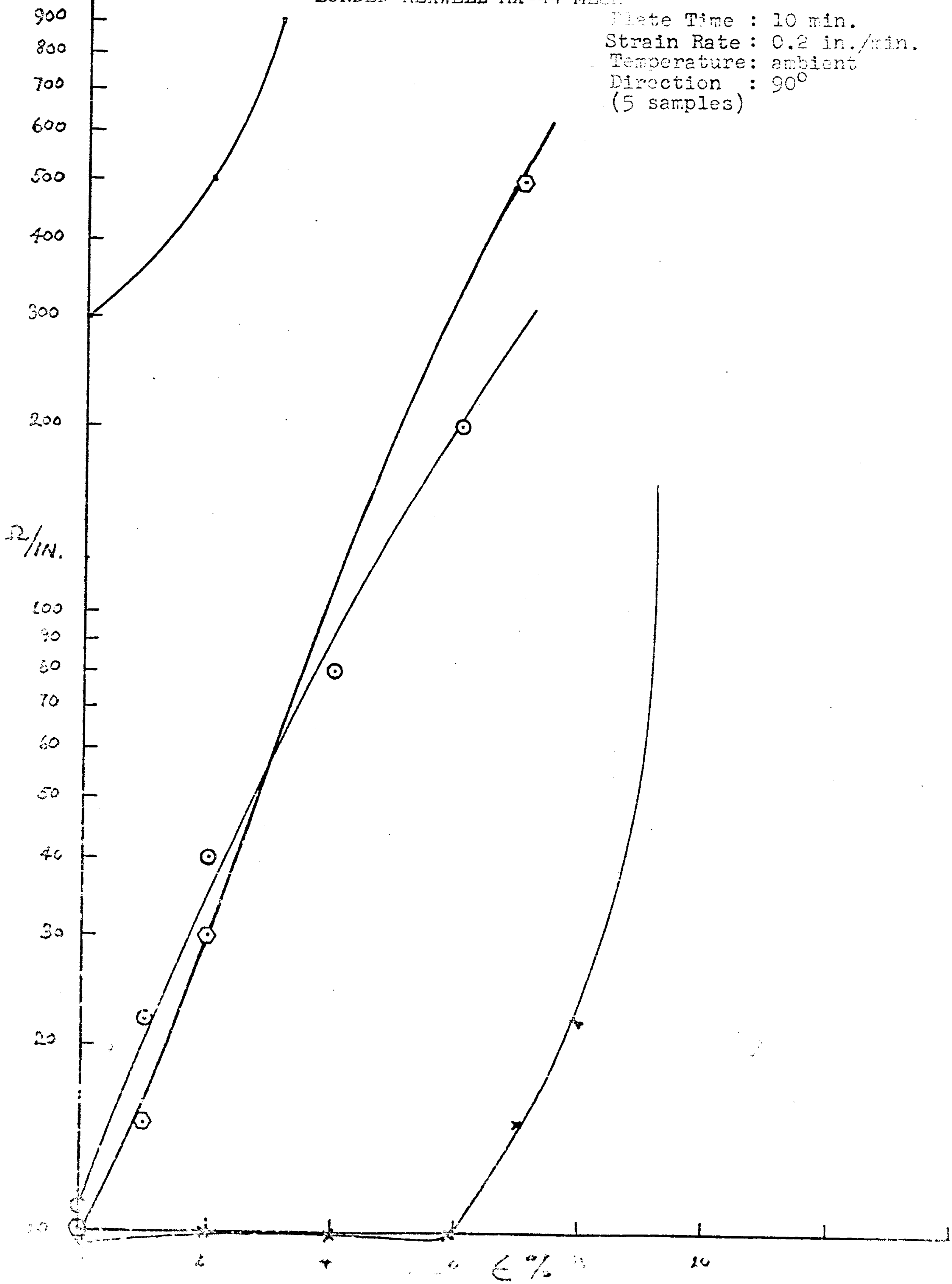


Figure 3 RESISTANCE VS. STRAIN CURVE PLATED AND ULTRASONICALLY BONDED REXWELL MX-44 MESH

Plate Time : 10 min.
Strain Rate : 0.2 in./min.
Temperature: ambient
Direction : 0°
(5 samples)

Figure 4 RESISTANCE VS. STRAIN CURVE PLATED AND ULTRASONICALLY BONDED REXWELL MX-44 MESH



3.0 IRRADIATED SEA SPACE POLYETHYLENE FILM

The effects of irradiation and heat treatment on ultrathin (0.15 mil) Sea Space polyethylene film were established. Samples of 0.15 mil polyethylene film were machine irradiated to 15 Mrads. The material was then heat treated at 105°C. for 16.3 hrs. To determine the effects of oxidation some samples were heat treated in air and some in nitrogen. After heat treatment tensile and shrinkage tests were performed.

3.1 Tensile Test Results

The results of the tensile tests are presented in Table 2.

Table 2

Tensile Properties of Sea Space 0.15 mil Irradiated Polyethylene Film

Atmosphere	$\sigma_y //$ (psi)	$\sigma_u //$ (psi)	$\epsilon_y //$ (%)	$\epsilon_m //$ (%)	$\sigma_y \perp$ (psi)	$\sigma_u \perp$ (psi)	$\epsilon_u \perp$ (%)	$\epsilon_m \perp$ (%)
Nitrogen	1160± 4	1388± 16	29±2	130± 0	851±45	851±45*	22±2	43±9
Air	1155±82	1263±187	32±5	97±10	692±35	692±35*	21±1	30±0

Irradiation Dose: 15 Mrads
Heat Treatment Temperature: 105°C.
Time: 16.3 hrs.

*Ultimate strength coincident with yield strength

Comparing these results with the results of Table IV of the June-August 1965 Quarterly Report, RAI 356, it can be seen that 15 Mrads of irradiation lowers the strength a slight amount and decreases the percent elongation. It can also be seen that the effect of an air atmosphere in heat treating degrades the polyethylene slightly.

3.2 Shrinkage Test Results

A circle of irradiated thin film having a radius of 5.8 cm. was heat treated at 105°C. for 16.3 hrs. in an unrestrained condition. The test was performed in both air and nitrogen. The distance from the center of the circle to the perimeter of the circle was measured after heat treating at different included angles between direction of measurement and the extrusion direction. The ratio of new dimension to the initial radius r/r_o was then plotted as a function of the included angle between measured radius and the extrusion direction. The results are presented in Figure 5. It can be seen that the maximum radial shrinkage, $1-r/r_o$, occurs at 0 and 180 degrees, i.e., the direction of extrusion, where r/r_o is a minimum. This maximum radial shrinkage observed is only about 7%. In general, the shrinkage of the irradiated film is less than that of the unirradiated film as can be seen by comparing Figure 5 with Figure 10 in the June-August 1965 Quarterly Report, RAI 356.

FIGURE 5 RADIAL SHRINKAGE OF UNRESTRAINED IRRADIATED [illegible] FILM UPON ANNEALING

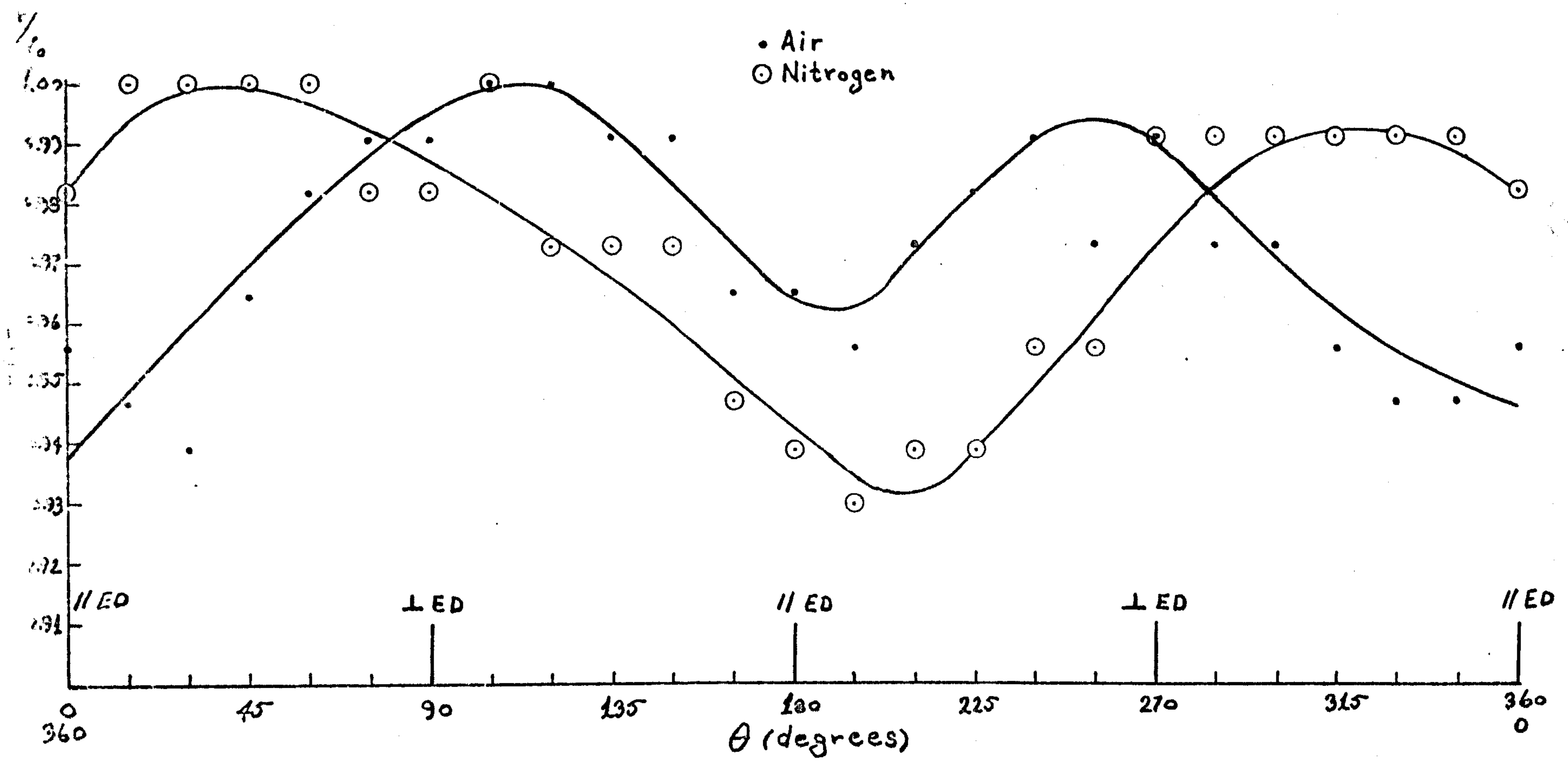
Film Thickness: 0.15 mil

Initial radius: 5.8 cm.

Annealing Temperature: 105±2°C.

Annealing Time : 16.3 hrs.

Irradiation : 15 Mrads



Included Angle Between Measured Radius and Extrusion Direction, Ø (degrees)

4.0 SELECTION OF INITIAL THIN POLYETHYLENE FILM

A tentative selection of thin polyethylene films for initial testing has been made. The films are Marlex 5003 and 6009 manufactured by Phillips Chemical Company. The significant properties of these films are listed in Table 3.

Table 3

Properties of Marlex Polyethylene Film

Film	Density (gm./cm3)	No. Average Molecular Weight (M_n)	Wt. Average Molecular Weight (M_w)	Crystalline Melting Point T_m(°C.)
Marlex 5003	0.950	9300-11,000	188,000-200,000	122
Marlex 6009	0.960	10,500	122,000	125

The ratio of M_w/M_n indicates that there is a wide distribution of molecular weights in these films. This situation is quite favorable for extraction. It indicates the possibility of extracting a large amount of low molecular weight material from the film leaving a matrix of crosslinked high molecular weight fractions.

5.0 FUTURE WORK

In the next reporting period other film suppliers aside from Phillips will be contacted so that their films can be evaluated. Once selection is made sufficient quantities of film will be ordered to pursue the testing program and construct the deliverable items. Work will also be continued on the establishment of the required minimum thickness of a polyethylene film that will be able to withstand a buckling pressure of five times solar pressure.

Additionally, metallizing, film perforating, ultrasonic bonding and irradiation companies will be contacted to establish their capabilities in processing the thin film to its final properties.